[Second Edition.]

PATENT SPECIFICATION

293,861

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COMPLETE SPECIFICATION.

Improvements in or relating to Radio Coupling Devices and Conductors therefor.

We, WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, of East Pittsburg, Pennsylvania, United States of America, a corporation organized and existing under the laws of the State of Pennsylvania, in said United States of America, Assignees of ROBERT LELAND DAVIS, of 215 N. Homewood Avenue, Pittsburgh, Pennsylvania, United States of America, a citizen of the United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The invention relates to radio coupling devices and particularly coupling transformers used between two vacuum tube devices.

It has been frequently the practice to insert in the plate circuit of one tube a parallel-resonant circuit or some other high impedance device including an inductor. The terminal of this impedance nearest the plate has frequently been connected to the grid of a second tube by a condenser and between said grid and the filament of the second tube a radio-frequency choke coil is frequently required.

The structure just described has several disadvantages among which may be mentioned that the inductance on either side of the connecting condenser may cooperate with the capacity between tube elements to give rise to troublesome parasitic oscillations. If, in order to avoid this, the two inductors are replaced by the two windings of a transformer, the leakage inductance of the transformer will co-operate with the tube capacities to cause parasitic oscillations. If the transformer be very closely coupled, the leakage inductance is small, but unless the leakage inductance is reduced to practically zero, the parasitic oscillations, although higher in frequency, continue to be troublesome.

Even when ordinary transformer coupling with no connecting condenser is used, the leakage inductance may give rise to trouble in this way. With the higher frequencies at which condenser coupling is usually employed, the trouble is more pronounced.

It is an object of this invention to provide a coupling between the vacuum tube devices which shall have a minimum tendency to produce parasitic oscillations.

It is a further object of this invention to provide a transformer, suitable for use in coupling two vacuum tube devices together, in which the leakage flux shall be very small.

It is a further object of this invention to produce a transformer in which the tightness of coupling shall be a maximum.

It is a further object of this invention to provide a capacity coupling which shall supplement the transformer coupling.

It is well known that leakage flux in the transformer usually results from the fact that the primary winding is necessarily spaced somewhat from the secondary winding. Numerous expedients have been adopted for diminishing the leakage, of which interleaving the windings is a common example. All such expedients result only in diminishing the separation between the primary and secondary.

Mathematical theory indicates that a current flowing in a tubular conductor is equivalent to a current flowing along the axis of the tube, and advantage is taken of this fact to produce a transformer in which the primary and secondary are, in effect, in identically the same place. Thereby the separation between the primary and secondary is, in effect, reduced to zero and the leakage of the transformer is, therefore, reduced to so small an amount that it is practically zero.

To this end one of the two windings is a tubular conductor and the other is placed in the axis of said tubular conductor. The tubular conductor is electrically equivalent to a linear conductor coinciding with the actual linear conductor. The two windings, therefore, act as if they were in the same place.

The invention will be more readily understood by reference to the accompanying drawing in which Fig. 1 is a diagram illustrating the use of the inven-

tion to couple two tubes. Fig. 2 is a showing, partly in section, of one form of the double conductor from which the coupling winding may be made, and Fig. 3 is a section upon an enlarged scale, showing another form of the insulation separating the two conductors.

In Fig. 1, the vacuum tube 1 is the final amplification stage from a master oscillator which is to control the frequency of the oscillations generated in the tube 2. The input circuit of the tube 1 extends from any suitable or known frequency-controlling device, such as a crystal-controlled oscillator or an oscillator controlled by a tuning fork. Between the oscillator itself and the input circuit, any number of amplifiers, frequency multipliers, or other similar devices may be inserted. The last of these devices is connected to the grid 4 and the filament 5 of the tube 1.

The output circuit of the tube 1 includes an adjustable condenser 6 and the usual by-pass condenser 7, which is in parallel to the battery 8 or other source of plate-current energy.

The inductance which is to co-operate with the condenser 6 to form a tuned circuit is supplied by one member of a double winding, which constitutes the important feature of the coupling device.

The double winding is composed of a tube 11 and a wire 12. The wire 12 extends along the axis of the tube 11. Contact between the wire and the walls of the tube is prevented by any convenient means.

In the illustration shown in Fig. 2, beads 13 of insulating material are threaded upon the wire 12 and the cylindrical surface of the beads contacts with the inside surface of the tube 11. It is not necessary that the beads shall make a close mechanical fit, either with the tube or with the wire. Neither is it necessary that the beads closely contact with each other at their ends.

It is preferable that all of these parts fit loosely enough to enable the compound conductor consisting of the wire 12 and the tube 11 to be wound into a helix, as shown in Fig. 1. If, however, the beads fit the wire and tube with a moderate degree of closeness, the helix will be self-supporting.

In the circuit shown in Fig. 1, the tube 11 is connected, as shown at 14 and 15, to the two sides of the condenser 6. The inductance of the primary 11 and the capacity of the condenser 6 are thus in parallel with one another and constitute the tuning elements in the plate circuit of the tube 1.

The helical wire 12 within the tubular conductor 11 is the secondary of the transformer and he terminal thereof adjacent the connection 14 is connected, as shown at 16, to the grid of the tube 2. Likewise, the other end of the helical wire is connected, as shown at 17, to the filament of the tube 2. The latter connection includes a condenser 18 in parallel to the grid-bias battery 19.

A certain capacity exists between the wire 12 and the tube 11. Consequently, there will be not only transformer coupling but also electrostatic coupling between the output circuit of the tube 1 and he input circuit of the tube 2. If desired, this capacity coupling may be supplemented by a condenser 20 connecting the conductors 14 and 16. A similar condenser 21, shown at the lower end of the helix will further supplement the capacity coupling.

If the transformer were absolutely without any leakage whatever, the radio-frequency potential at any point along the wire 12 would be the same as the radio-frequency potential at the neighbouring point in the tube 11. No condenser action would, therefore, take place and the capacity coupling would be without effect. It is to supplement the incomplete transformer-coupling which must in practice exist that the capacity coupling is of use.

The tube 2 is a power tube. Its output circuit 22 is supplied by means of a high-potential source 23 which is in parallel with the usual by-pass condenser 24 and the output circuit delivers power to the antenna in the usual way.

The filaments are grounded, as usual, and are supplied in parallel from the common cathode battery 26. An adjustable resistor 27 is shown for controlling the heating of both filaments and a supplementary rheostat 28 is supplied for additional control of the filament 5, if desired.

In installations intended for high power, it is preferred that the beads, instead of having plain ends, as shown in Fig. 2, shall be formed with ends which dove-tail, as illustrated in Fig. 3. One end of each bead is furnished with a projecting central portion 30, and the other end of each bead is provided with a corresponding recess 31. When the beads are threaded upon the wire 12, the protruding parts are all directed in the same way relative to the wire, whereby the projections on each bead fit into the recesses in the neighbouring bead. Preferably, the fitting is not close, in order that the compound conductor may be bent into the helical form.

In the operation of the device, the

oscillations from the master oscillator are amplified by the tube 1 and produce oscillations, of the same frequency or its harmonic, in the circuit 6—11 which is tuned to said oscillations or to said harmonic.

The oscillations in the primary 11 give rise to an alternating flux through the helix composed of the wire 12 and electromotive forces are set up in this wire as a consequence of the alternations in said flux. If the transformer coupling is not absolutely without leakage, the changes in voltage upon the tube 11 induce changes in voltage upon the wire 12 electrostatically, which constitute an addition to the electromotive forces already noticed. If the condenser 20 is employed, still further potential changes are conveyed by it. All of these potential changes are so related in phase that an additive result is impressed upon the conductor 16, and thus upon the grid of the tube 2.

The condenser 21 also adds to the electrostatic coupling. Although a connection from one side of this condenser to the other can be traced through batteries 8 and 19 in series, this connection includes the battery leads, which, ordinarily are long and, therefore, possess a substantial amount of inductance. Some difference of alternating potential is, therefore, present across the condenser 21 and this alternating potential difference acts upon the grid of the tube 2 in the same sense as the potential changes already noted.

The direct current source 8 is larger than the direct current source 19. Moreover, the negative terminal of the source 19 is connected to the wire 12 and the positive terminal of the source 8 is connected to the tube 11. The other terminals of each of said sources are connected, either directly or through a relatively small resistance, to ground. Consequently, the wire 12 is at a lower direct current potential than the tube 11. When the device is used in high power transmitting apparatus, this difference of direct current potential is of substantial amount, and the tube 11 must be thoroughly insulated from the wire 12. Under such circumstances, the structure shown in Fig. 3 is preferred, because the bends in the leakage path over the end surfaces of the beads 13 cause the path to be longer than in the case of beads with plane ends.

The wire 12 is in the position occupied by the axis of the tube 11. The tube is electrically equivalent to a conductor in this position. There is, therefore, no separation between the primary and secondary. Substantially all flux which links the primary will, therefore, link the secondary and, consequently, substantially no leakage occurs as a result of separation between primary and secondary. Because the leakage will be very small, the likelihood of parasitic oscillations being set up is also small. It is not, however, completely removed. The inductance in the leads 14 and 15, for example, may cause parasitic oscillations.

The absence of substantially all leakage inductance ensures that the potential will vary along the tube at the same rate that it does along the wire. Each point of the wire, therefore, is at the same alternating-current potential as its neighbouring point in the tube. The insulation 13 is, therefore, not subject to an alternating electrostatic field and high frequency losses will not be produced in such insulation. It is, therefore, possible to make the beads 13 of material which would not be suitable for use in places where alternating high frequency electric fields are present. Ordinary glass will be suitable or the beads may be made of mouldable material.

The illustration in Fig. 1 of the coupling between the final amplification stage of the master oscillator and the power tube is by way of example only. The invention may be applied to the coupling between any two tubes.

Also the association of the coiled compound conductor with a tuned circuit, such as that of which the condenser 6 forms a part is not essential. It may form a part of an untuned coupling. Whenever there is a tuning condenser, it is preferable that it be associated with the tube instead of the wire because the tube affords a greater surface for carrying the alternating current.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. In a vacuum tube system, the combination with a pair of tubes of a coupling transformer comprising a tubular conductor in the form of a helix and a conductor within and insulated from the tubular conductor and thereby constituting a second helix, substantially as and for the purpose described.

2. A double radio conductor capable of being wound into helical form, comprising a wire having a plurality of adjacent insulating beads threaded thereon and a tubular conductor held spaced from said wire by said beads, substantially as described.

3. Radio tube systems having con-

centric conductor coupling transformers, substantially as described.

4. Radio coupling transformers comprising double conductors constructed substantially as described and shown on the accompanying drawing.

Dated the 26th day of June, 1928.

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2nd Edition

[This Drawing is a reproduction of the Original on a reduced scale]

Fig. 1.

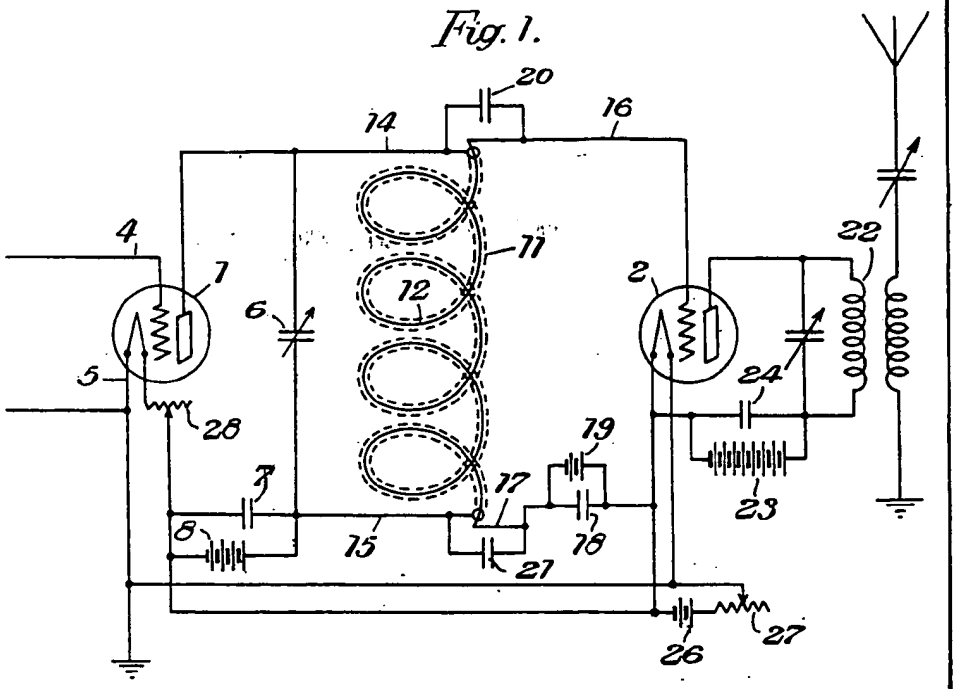


Fig. 2.

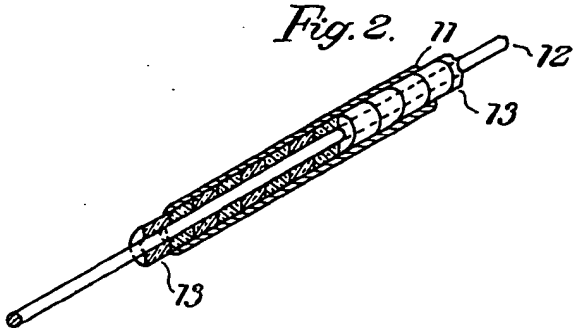
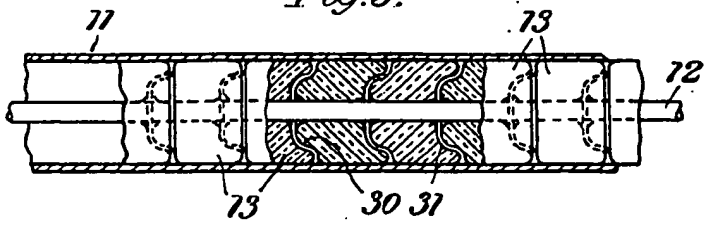


Fig. 3.



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